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# NOTES AND LITERATURE

## SUNSPOTS, CLIMATIC FACTORS AND PLANT ACTIVITIES

VARIATIONS in solar radiation, if of sufficient magnitude, should be followed by variations in terrestrial climatic conditions. In the absence of long series of determinations of the heat radiated by the sun, meteorologists have turned to variation in the number of sunspots as a possible factor underlying variation in the climatic factors. This involves the assumption that a period of many sunspots differs from a period of few spots in heat and light radiation.

If such climatic factors as heat and precipitation be closely related to the number of sunspots, the number of sunspots should be a factor of importance in determining plant activities. In recent years attempts have been made to correlate growth, especially that recorded in the annual rings of trees, with number of sunspots.[1]

Since any attempt to relate growth phenomena to sunspot number presupposes relationships between climate and sunspot frequency, the botanist should be interested in the attempts of the meteorologist to ascertain the relationship between solar and terrestrial atmospheric phenomena. The purpose of this review is to call attention to certain recent discussions of this subject. For a review of earlier literature, the reader must refer to Hann's "Handbook of Climatology" and to the careful discussion from the biological side in Chapter XIX of Huntington's "Climatic Factor."[2]

Heretofore, those who have discussed the interdependence of terrestrial and solar phenomena have been content to plot curves for the two phenomena and to determine the existence of relationship between them by similar trends in the two curves.

The sources of error in such a method are very great. Furthermore, it gives no quantitative measure of intensity of relationship. Such a measure can only be secured by means of some correlation or contingency coefficient.

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[1] Douglas, A. E., "A Method of Estimating Rainfall by the Growth of Trees." In Ellsworth Huntington's "The Climatic Factor," pp. 101–121.

[2] Huntington, E., "The Climatic Factor as Illustrated in Arid America," Pub. Carn. Inst. Wash., 192, 1914.

Walker,[3] the director general of observatories for India, has made a great advance in the investigation of the possible relationship between the number of sunspots and meteorological phenomena by applying the modern methods of correlation to the problem.

I have tabulated his three series of correlations for a large number of stations widely distributed over the earth, with the results given in the accompanying table.

| Intensity of Correlation | Frequency of Correlations | | |
|---|---|---|---|
| | Sunspots and Rainfall | Sunspots and Temperature | Sunspots and Pressure |
| – .59 to – .53 | — | 2 | — |
| – .52 to – .46 | 1 | 1 | 2 |
| – .45 to – .39 | 1 | 6 | 2 |
| – .38 to – .32 | 6 | 7 | 3 |
| – .31 to – .25 | 9 | 10 | 8 |
| – .24 to – .18 | 17 | 12 | 8 |
| – .17 to – .11 | 15 | 15 | 8 |
| – .10 to – .04 | 21 | 14 | 15 |
| – .03 to + .03 | 27 | 16 | 11 |
| + .04 to + .10 | 13 | 4 | 8 |
| + .11 to + .17 | 18 | 5 | 10 |
| + .18 to + .24 | 9 | 4 | 8 |
| + .25 to + .31 | 7 | 1 | 6 |
| + .32 to + .38 | 6 | — | 2 |
| + .39 to + .45 | — | — | — |
| + .46 to + .52 | 1 | — | — |
| Total number of stations. | 151 | 97 | 91 |

Remembering that correlation is measured on a scale of — 1 to + 1, this table shows at once that there is no uniformity for the globe as a whole in the correlations between number of sunspots and either of the climatic factors considered. Instead coefficients for some stations are positive while those for others are negative. Thus as far as the data available go, they indicate that in some regions rainfall, temperature or barometric pressure are higher in periods of larger numbers of sunspots, whereas in other regions they are lower. The magnitude of the coefficients is generally low.[4] Over thirty per cent. of the constants lie between + .10 and — .10. The probable errors of the constants are of about this magnitude.

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[3] Walker, Gilbert T., "Correlation in Seasonal Variation of Weather," IV–VI. Mem. Ind. Met. Dep., 21: 10–12, 17–118, 3 world maps, 1915.

[4] These correlations are based on such small samples that for their full interpretation the theory of the distribution of small correlations now being developed by "Student," Soper, Fisher, Young, Cave, Lee and Pearson must be considered. Nothing brought out by the work of these writers, which will be reviewed later, invalidates the general correctness of the conclusions reached here.

The average values of the three sets of correlations are:

For sunspots and rainfall, 151 stations, $\bar{r} = -.0175$
For sunspots and temperature, 97 stations, $\bar{r} = -.1360$
For sunspots and pressure, 91 stations, $\bar{r} = -.0331$

While these averages are exceedingly small, all are negative in sign, indicating that for the globe as a whole lower rainfall, temperature and barometric pressure are associated with greater numbers of sunspots.

The same relationship is apparent if only the 76 stations for which all three relationships have been calculated be considered. The averages are:

For sunspots and rainfall, $\bar{r} = -.0349$
For sunspots and temperature, $\bar{r} = -.1534$
For sunspots and pressure, $\bar{r} = -.0486$

If in obtaining the average correlations the constants for the several stations are weighted with the number of years for which records are available the averages, indicated by the bars, are:

For sunspots and rainfall, 151 stations, $\bar{\bar{r}} = -.0103$
For sunspots and temperature, 97 stations, $\bar{\bar{r}} = -.1243$
For sunspots and pressure, 91 stations, $\bar{\bar{r}} = -.0387$

Thus, however calculated, the averages indicate generally negative values of the correlation coefficient for all three relationships.

The same fact is brought out if the coefficients are classified according to sign only. Thus:

| Number of Sunspots and: — | Frequency of Positive Correlation | Frequency of Zero Correlation | Frequency of Negative Correlation |
|---|---|---|---|
| Rainfall | 70 | 1 | 80 |
| Temperature | 18 | 4 | 75 |
| Pressure | 38 | 3 | 50 |

For all three relationships the negative correlations are more numerous than those which are positive in sign.

In a brief review it is quite impossible to give in detail the meteorological considerations discussed in the original memoirs. Furthermore, the most of these do not directly concern the botanist. The conclusions of practical biological importance to be drawn from Walker's investigations seem to be the following:

*a.* The relationship between the number of sunspots and the annual record of terrestrial meteorological phenomena is very slender indeed. It is so slight that at the present time it is impossible to assert on the basis of the data of any one station alone that any relationship at all exists. Thus, as far as they go, these data hold out very little hope to the biologist of being able to correlate plant activities with sunspot number, unless light intensity be the means of solar influence.

*b.* For rainfall and barometric pressure the correlations are especially low. They average practically zero, but are apparently on the whole negative in sign.

*c.* The correlation between number of sunspots and terrestrial temperature is the most consistent and substantial of the three. The coefficients average about — .14. Thus years of larger numbers of sunspots are in the long run years of lower, *not higher,* terrestrial temperature.[5]

These results are directly opposed to the theories which seem to have prevailed among many writers.

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[5] Possibly, as Walker suggests, superheating in equatorial regions may raise the temperature in the upper air but lower that at ground level. The temperatures in which the botanist is primarily interested are, however, those which may influence the film of vegetation which covers the globe.